

Increase of Lichen Diversity in the Imperial Palace Grounds, Tokyo, Japan

Yoshihito Ohmura^{1*}, Göran Thor², Andreas Frisch¹,
Hiroyuki Kashiwadani¹ and Kwang Hee Moon³

¹Department of Botany, National Museum of Nature and Science,
4–1–1 Amakubo, Tsukuba, Ibaraki 305–0005, Japan

*E-mail: ohmura-y@kahaku.go.jp

²Department of Ecology, Swedish University of Agricultural Sciences,
P.O. Box 7044, SE-750 07 Uppsala, Sweden

³Biological Resources Research Department, National Institute of Biological Resources,
Gyoungser-dong, Seo-gu, Incheon, 404–170 Korea

Abstract. The lichen flora in the Imperial Palace Grounds, Tokyo, was investigated in 2009–2013. A total of 98 species of lichens and related fungi were found during the investigation, which is almost doubled compared to a previous study in 1995–1996 when 57 species were discovered. Eight species found in 1995–1996 were not found again in 2009–2013. A Total of 106 species has been found during the investigations in 1995–1996 and 2009–2013. *Enterographa hutchinsiae* and *Porina leptalea* are reported as new to Japan, while *Arthonia pertabescens*, *Aspicilia cinerea*, *Chaenotheca hygrophila*, *Coenogonium pineti*, *Cresponea japonica*, *Endocarpon petrolepideum*, *Graphis handelii*, *G. scripta*, *Lecanora leprosa*, *Lithothelium japonicum*, *Normandina pulchella*, *Pertusaria pertusa*, *Sculptolumina japonica*, and *Thelidium japonicum* are new to the Imperial Palace Grounds. Forty-six species could only be determined to genus and three species are indicated as Lichen sp. for the specimens collected through both investigations in 1995–1996 and 2009–2013. Twenty-three of the species determined only to genus and as Lichen sp. are also new to the investigated area. The increase in lichen diversity is probably caused by the reduction of air pollution due to new regulations regarding exhaust emissions from automobiles in and around Tokyo, established in 2003.

Keywords: Air pollution, bioindicator, crustose lichens, macrolichens, monitoring, urban area.

Introduction

The Imperial Palace Grounds (35°41'N, 139°45'E) is located at the center of downtown Tokyo and upheld a rather stable natural environment over a period of several centuries, in spite of frequent fires, earthquakes, and warfare including the devastating air raids of World War II.

Lichens grow in various habitats in the Imperial Palace Grounds, including ancient stone walls, old alley trees, mortar, and the nemoral deciduous forest covering parts of the area. For a detailed description of these lichen habitats, see Kashiwadani and Thor (2000).

As a part of biological investigations in the Imperial Palace Grounds in Tokyo conducted by the National Museum of Nature and Science, the first lichen inventory of the area took place in 1995–1996. Fifty-seven species, including four macrolichens and 53 crustose species were reported (Kashiwadani and Thor 1997, 2000). A second lichen inventory was performed in 2009–2013 with the intention to monitor possible floristic changes since the first inventory. In a first publication from this project, Ohmura *et al.* (2012) reported 16 species of macrolichens found during 2009–2010, which is a fourfold increase in macrolichen species diversity.

The aim of the present paper is to (1) present a summary of the inventories of 1995–1996 and 2009–2013, (2) compare the results of the inventory of 2009–2013 with the previous inventory, (3) provide short morphological descriptions and notes on the habitat for species not earlier reported from the Imperial Palace Grounds, and (4) provide a key to all species. In addition to the lichens, one lichenicolous fungus within the mainly lichenized genus *Arthonia* (*Arthonia* sp. 2) is treated here as well as two species from the non-lichenized fungal genus *Lichenothelia* which is traditionally covered by lichen floras.

Materials and Methods

The collection sites are shown in Table 1 and Fig. 1. All specimens are housed at the herbarium of the National Museum of Nature and Science (TNS) with duplicates of selected specimens kept at the Museum of Evolution at Uppsala University (UPS). Morphological descriptions were made using a dissecting microscope and a differential interference contrast microscope on material mounted in GAW solution (glycerol:ethanol:water = 1:1:1). The iodine colouration (Lugol's solution, iodine concentration 0.25%) was studied both with and without pre-treatment with K, the former coloration here denoted as the K/I coloration, the latter as the I coloration. Thin layer chromatography (TLC) was carried out in accordance with the method described by White and James (1985). The B- and C-solvent systems were used. Due to regulations for the collection of lichen specimens in 2009–2013 saxicolous species were only partly collected (but were always recorded and are listed below).

Results and Discussion

During the investigations in 1995–1996 and 2009–2013, a total of 106 lichens and related fungi have been found (Appendix 1). A total of 98 species were found in the current inventory 2009–2013. Eight species found in 1995–1996 were not found again. *Enterographa hutchinsiae*

and *Porina leptalea* are reported as new to Japan, while *Arthonia pertabescens*, *Aspicilia cinerea*, *Chaenotheca hygrophila*, *Coenogonium pineti*, *Cresponea japonica*, *Endocarpon petrolepideum*, *Graphis handelii*, *G. scripta*, *Lecanora leprosa*, *Lithothelium japonicum*, *Normandina pulchella*, *Pertusaria pertusa*, *Sculptolumina japonica*, and *Thelidium japonicum* are new to the Imperial Palace Grounds. Forty-six species could only be determined to genus and three species are indicated as Lichen sp. for the specimens collected through both investigations in 1995–1996 and 2009–2013. Twenty-three of the species determined only to genus and as Lichen sp. are also new to the investigated area. With a total 98 species in 2009–2013, the lichen diversity of the Imperial Palace Grounds has almost doubled compared to the inventory in 1995–1996 when 57 species were discovered. The most notable change was observed for the species of macrolichens with a fourfold increase in species numbers.

Key to species

Specimens without ascomata are rather frequent and are included in the key. *Lecanora pulverulenta* and *Lecanora* sp. are keyed out both with and without apothecia. *Agonimia pacifica* is keyed out both with and without perithecia even though not found with perithecia in the Imperial Palace Grounds.

1. Thallus lichenicolous or thallus of non-lichenized black areoles, ≤ 0.1 mm in diam. 2
1. Thallus lichenized 4
2. Lichenicolous on thalli of *Physciella melanchra*, forming blackish convex ascomata; spores hyaline, 1-septate **Arthonia** sp. 2
2. Thallus of black areoles 3
3. Thallus of scattered areoles; spores $8\text{--}10 \times 5 \mu\text{m}$ **Lichenothelia** sp. 1
3. Thallus of aggregated areoles; spores $14 \times 6 \mu\text{m}$ **Lichenothelia** sp. 2
4. Thallus foliose or fruticose 5
4. Thallus crustose or squamulose 20

Table 1. List of localities. All localities: Japan, Honshu, Prov. Musashi (Tokyo Metropolis), Chiyoda-ku, Imperial Palace grounds, N35°41', E139°45'.

Locality number (see Fig. 1)	Abbreviation	Locality	Collection date (d/m/y)	Note
1	Agency	Concrete wall in front of the Imperial Household Agency, elev. 15 m	7/3/2013	North-facing vertical concrete wall
2	Chikurin	Chikurin, elev. 30 m	7/3/2013	Old growth deciduous forest along a road
3	Fukiage	Fukiage-gyoen, elev. 13 m	26/10/2009	Old growth deciduous forest with paths
4	Hanzo	Around Hanzo-bori Moat, elev. 35 m	7/3/2013 13/10/2010 7/3/2013 18/7/2013	West-facing old stone wall, not shaded by trees
5	Honmaru	Honmaru, Higashi-gyoen, elev. 20 m	14/10/2010	Open place with scattered deciduous trees
6	Inui	Inui-mon avenue, elev. 10 m	26/10/2009 3/12/2009 4/12/2009 7/1/2010 6/3/2013 18/7/2013	Avenue with <i>Prunus</i> × <i>yedoensis</i> and scattered <i>Acer</i> spp.
7	Kamidokan	Around Kamidokan-bori Moat, elev. 20–40 m	13/10/2010 8/3/2013	West-facing old stone wall surrounded by open forest along narrow road (elev. 40 m); and mixed humid forest with scattered <i>Cryptomeria japonica</i> trees (elev. 20 m)
8	Kanbaku	Kanbaku-tei, Fukiage-gyoen, elev. 15 m	7/3/2013	Oldgrowth deciduous forest with scattered rocks near a small stream
9	Kashiko	Kashiko-dokoro, elev. 20 m	8/3/2013 18/7/2013	Old <i>Prunus</i> sp.
10	Kikyō	Tatsumiyagura, Kikyōbori Moat, Higashi-gyoen, elev. 4 m	14/10/2010	Open place with scattered broadleaf evergreen tree and pine trees
11	Nantei	Kyuden-Nantei (Imperial Palace south garden), elev. 25 m	8/3/2013 18/7/2013	Exposed rocks along small stream in Japanese garden; and pebbles on the grounds of small house
12	Ohmichi	Ohmichi garden, elev. 10 m	4/12/2009 6/3/2013	Nursery with bonsai trees, scattered other trees and greenhouses
13	Sakashita	Sakashita-mon, Imperial Palace, elev. 10 m	3/12/2009 7/3/2013 18/7/2013	Open place nearby the gate with north-east-facing old stone wall and scattered trees
14	Sakurada	Along road parallel to Sakurada-bori moat, elev. 15 m	7/3/2013 18/7/2013	Old growth forest along a road
15	Sankaku	Stone wall near Sankaku-mon, elev. 10 m	4/12/2009 8/3/2013 18/7/2013	Shaded old stone wall
16	Shimodokan	Shimodokan-bori Pond, elev. 10 m	6/3/2013	North-west facing old stone wall beside moat

- | | | |
|--|----|---|
| 5. Thallus foliose | 6 | lower surface ... Parmelinopsis minarum |
| 5. Thallus fruticose | 18 | 9. Rhizines lacking on the marginal zone of the lower surface |
| 6. Thallus yellow to greenish yellow | 7 | Parmotrema tinctorum |
| 6. Thallus grey to greenish grey | 8 | 10. Thallus maculate on the upper cortex |
| 7. Lobes narrow (1–3 mm); calycin (major) and pulvinic dilactone (minor) | | Parmotrema clavuliferum |
| Candelaria concolor | | 10. Thallus emaculate on the upper cortex |
| 7. Lobes broad (3–5 mm); caperatic acid | | 11 |
| Flavoparmelia caperata | | 11. Pseudocyphellae present on the upper cortex |
| 8. Isidia present | 9 | Punctelia borreri |
| 8. Isidia absent | 10 | 11. Pseudocyphellae absent on the upper cortex |
| 9. Rhizines reaching the margins on the | | 12 |

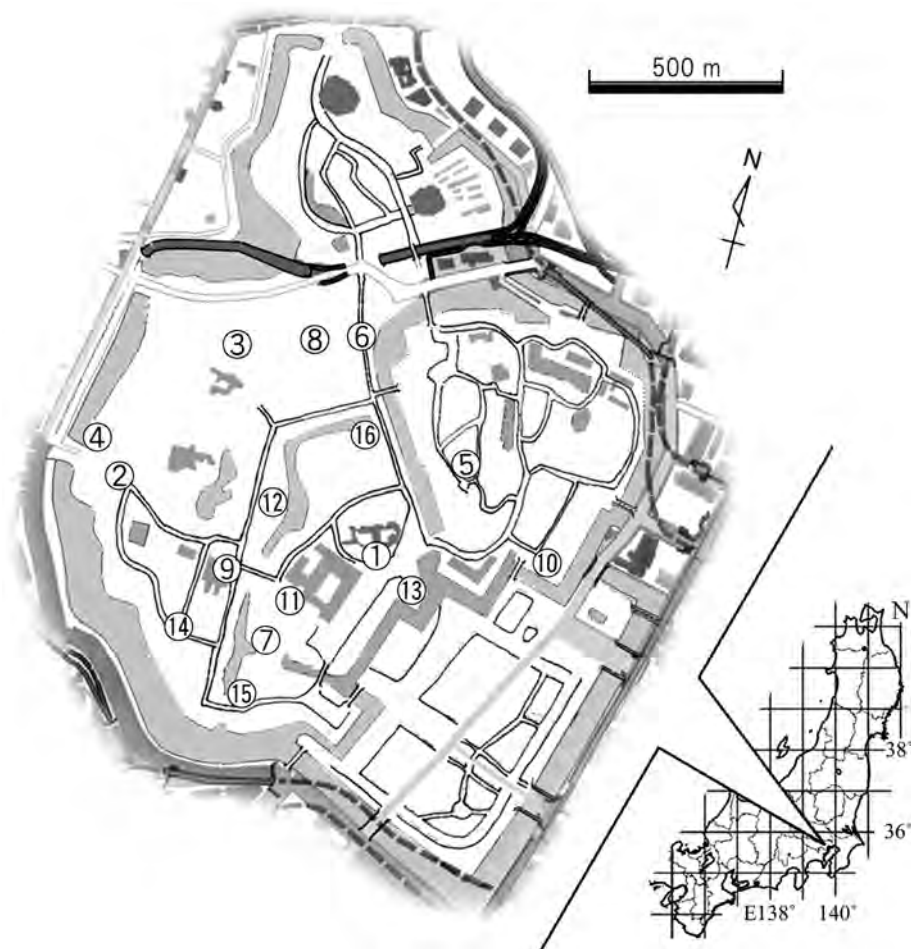


Fig. 1. Collection sites in the Imperial Palace Grounds. Locality numbers and abbreviation of locality names are identical with those in Table 1. 1: Agency, 2: Chikurin, 3: Fukiage, 4: Hanzo, 5: Honmaru, 6: Inui, 7: Kamidokan, 8: Kanbaku, 9: Kashiko, 10: Kikyo, 11: Nantei, 12: Ohmichi, 13: Sakashita, 14: Sakurada, 15: Sankaku, 16: Shimodokan.

- | | |
|--|--|
| <p>12. <i>Soralia marginal</i>
 <i>Parmotrema austrosinense</i></p> <p>12. <i>Soralia laminal</i> 13</p> <p>13. Medulla orange
 <i>Phaeophyscia rubropulchra</i></p> <p>13. Medulla white 14</p> <p>14. Thallus margin with a tint of orange pigment
 <i>Hyperphyscia crocata</i></p> <p>14. Thallus margin without pigment 15</p> <p>15. Thallus white to whitish grey 16</p> <p>15. Thallus greenish grey or brownish grey
 17</p> <p>16. Lobes confluent <i>Dirinaria applanata</i></p> | <p>16. Lobes discrete <i>Physcia orientalis</i></p> <p>17. Lobes broad (2–3 mm); lower cortex paraplectenchymatous
 <i>Phaeophyscia hispidula</i></p> <p>17. Lobes narrow (<1 mm); lower cortex prosoplectenchymatous
 <i>Physciella melanchra</i></p> <p>18. Podetia cup-shaped; atranorin present
 <i>Cladonia kurokawae</i></p> <p>18. Podetia single, not cup-shaped; atranorin absent 19</p> <p>19. Primary thallus subdigitately-laciniate; homosekikaic acid absent.....</p> |
|--|--|

- **Cladonia caespiticia**
19. Primary thallus squamulose; homosekikaic acid present **Cladonia ramulosa**
20. Thallus squamulose 21
20. Thallus crustose 26
21. Thallus blue-grey, ear-like lobes with raised margins and clusters of soredia
..... **Normandina pulchella**
21. Thallus greenish-grey to brownish grey, without ear-like lobes 22
22. Thallus minutely squamulose (0.1–1 × 0.1–0.3 mm), green with a brown tint
..... **Agonimia pacifica**
22. Squamules larger, without a brown tint 23
23. Thallus lower surface very pale brown to whitish **Endocarpon neopallidum**
23. Thallus lower surface black 24
24. Squamules attached to the substratum only at the basal to central parts
..... **Endocarpon superpositum**
24. Squamules adnate 25
25. Squamules lobate; lobes repeatedly and radiately branched, more or less linear
..... **Endocarpon japonicum**
25. Squamules simple or shallowly lobate; lobes rotund
..... **Endocarpon petrolepideum**
26. Thallus and/or apothecia yellow to orange 27
26. Thallus and/or apothecia not yellow to orange 30
27. Thallus and/or apothecia K –
..... **Candelariella** sp.
27. Thallus and/or apothecia K + violet–red 28
28. Thallus sorediate, apothecia lacking
..... **Caloplaca** aff. **citrina**
28. Thallus not sorediate, apothecia common 29
29. Thallus ± yellow **Caloplaca** sp. 1
29. Thallus greyish **Caloplaca** sp. 2
30. Ascumata present 31
30. Ascumata absent 86
31. Ascumata distinctly stalked 32
31. Ascumata sessile to immersed 33
32. Thallus lichenized, spores non-septate, spherical, 3–4 μm in diam.
..... **Chaenotheca hygrophila**
32. Thallus non-lichenized, spores 1-septate, 5–5 × 1.5–2 μm
..... **Chaenothecopsis nigra**
33. Ascumata perithecia 34
33. Ascumata apothecia 46
34. Spores brown 35
34. Spores colourless 36
35. Ascumata with lateral ostioles; spore lumina rounded
..... **Lithothelium japonicum**
35. Ascumata with apical ostioles; spore lumina angular **Pyrenula** sp.
36. Spores non-septate 37
36. Spores transversally septate to muriform
..... 40
37. Thallus grey; on mortar
..... **Verrucaria** sp. 4
37. Thallus variously coloured; not on mortar 38
38. Thallus black; spores 12–15 × 5 μm
..... **Verrucaria** sp. 3
38. Thallus not black; spores 14–27 × 8–17 μm 39
39. Thallus greenish grey; spores 14–22 × 9–12 μm **Verrucaria** sp. 1
39. Thallus whitish grey; spores 21–27 × 12–17 μm **Verrucaria** sp. 2
40. Photobiont *Chlorococcales* 41
40. Photobiont trentepohlioid 42
41. Spores 1-septate
..... **Thelidium japonicum**
41. Spores muriform **Polyblastia** sp.
42. Spores 1-septate **Strigula** sp.
42. Spores 3–8-septate 43
43. Perithecia often with at least some whitish hairs; spores 5(–6)-septate
..... **Porina hirsuta**
43. Perithecia not with whitish hairs; spores 3-septate or 7–8-septate 44
44. Perithecia dark red **Porina leptalea**
44. Perithecia blackish 45
45. Perithecia up to 0.1 mm in diam.; spores 3-septate, 22–23 × 5 μm **Porina** sp. 1

45. Perithecia up to 0.2 mm in diam.; spores 7–8-septate, $40\text{--}41 \times 3 \mu\text{m}$... **Porina** sp. 2
46. Spores brown 47
46. Spores colourless 51
47. Thallus sorediate **Buellia** sp. 2
47. Thallus not sorediate 48
48. Apothecia immersed 49
48. Apothecia sessile 50
49. Spores 1-septate, brown **Buellia** sp. 1
49. Spores non-septate, colourless **Aspicilia** sp.
50. Thallus partly K+ purple (anthraquinones); hymenium inspersed, spores with thickened inner walls (Mischoblastia-type) **Sculptolumina japonica**
50. Thallus K-; hymenium not inspersed; spores with thin inner walls **Amandinea punctata**
51. Photobiont cyanobacteria 52
51. Photobiont not cyanobacteria 53
52. Photobiont *Gloeocapsa*; asci 8-spored **Pyrenopsis** sp.
52. Photobiont *Pleurocapsales*; asci ca. 36–48-spored **Lichinella japonica**
53. Photobiont trentepohlioid 54
53. Photobiont *Chlorococcales* or micareoid 66
54. Spores 1-septate 55
54. Spores ≥ 5 -septate 57
55. Apothecia with dentate margins **Coenogonium kawanae**
55. Apothecia without dentate margins 56
56. Apothecia up to 0.25 mm in diam.; spores $9\text{--}10 \times 3 \mu\text{m}$; conidia 1-septate, $12\text{--}13 \times 2 \mu\text{m}$ **Coenogonium dilucidum**
56. Apothecia up to 0.5 mm in diam.; spores $9\text{--}15 \times 2\text{--}4.5 \mu\text{m}$; conidia non-septate, $6\text{--}8 \times 1.8\text{--}2.6 \mu\text{m}$ **Coenogonium pineti**
57. Spores I+ violet, thick-walled 58
57. Spores I-, \pm thin-walled 59
58. Hymenium inspersed; K+ yellow to red, norstictic acid present **Graphis handelii**
58. Hymenium not inspersed; K-, norstictic acid absent **Graphis scripta**
59. Apothecia urceolate; spores with an up to $2.5 \mu\text{m}$ thick episore ... **Ramonia luteola**
59. Apothecia not urceolate; spores without or with a thinner episore 60
60. Apothecia \pm round 61
60. Apothecia elongate 62
61. Apothecia sessile ... **Cresponea japonica**
61. Apothecia immersed **Arthonia pertabescens**
62. Apothecia with a reduced, colourless to brownish excipulum 63
62. Apothecia with a well-developed, black, carbonaceous excipulum 64
63. Spores 6–11-septate, $25\text{--}50 \times 2.3\text{--}3 \mu\text{m}$, with an up to $2.5 \mu\text{m}$ thick episore **Enterographa anguinella**
63. Spores 4–6-septate, $22\text{--}30 \times 4\text{--}5 \mu\text{m}$, with a thinner gelatinous sheath; confluent acid **Enterographa hutchinsiae**
64. Hymenium I+ pale orange-red **Opegrapha** sp. 2
64. Hymenium or hypothecium at least partly I+ blue 65
65. Spores 3–5-septate, $22\text{--}31 \times 4.5\text{--}6 \mu\text{m}$; hypothecium persistently I+ blue **Opegrapha** sp. 1
65. Spores 6–8-septate, $21\text{--}26 \times 3\text{--}5 \mu\text{m}$; uppermost $15 \mu\text{m}$ of the hymenium persistently I+ blue **Opegrapha** sp. 3
66. Asci > 8 -spored 67
66. Asci 8-spored 69
67. Asci ca. 16-spored ... **Lecanora japonica**
67. Asci > 100 -spored 68
68. Apothecia deeply immersed; asci > 200 -spored, spores $3\text{--}5 \times 1\text{--}2 \mu\text{m}$ **Acarospora** sp.
68. Apothecia \pm sessile; asci > 100 -spored; spores globose, $2\text{--}3 \mu\text{m}$ in diam. **Strangospora** sp.
69. Photobiont micareoid **Micarea** sp.
69. Photobiont not micareoid 70
70. Spores 1–7-septate 71
70. Spores non-septate 76
71. Spores constantly 1-septate **Lecania erysibe**
71. Spores 1–7-septate 72
72. Spores spirally twisted in asci 72

- **Scoliosporum umbrinum**
72. Spores not spirally twisted in asci 73
73. Spores 4–7 μm broad, hypothecium K + brownish red to violet red **Bacidia** sp. 2
73. Spores 1.5–2 μm broad; hypothecium K – 74
74. Hypothecium brown; spores clavate **Bacidia** sp. 1
74. Hypothecium pale; spores acicular 75
75. Spores 1–3-septate, 21–26 \times 1.5 μm **Bacidina** sp. 2
75. Spores 7–8-septate, 39–43 \times 2 μm **Bacidia** sp. 3
76. Several apothecia immersed in fertile thallus warts 77
76. Apothecia not immersed in fertile warts 78
77. Asci 2-spored; spores 95–130 \times 30–34 μm **Pertusaria pertusa**
77. Asci 8-spored; spores 52–60 \times 20–24 μm **Pertusaria** sp.
78. Thallus with a bluish tint, C + red (gyrophoric acid) **Trapelia coarctata**
78. Thallus without bluish tint, C – (gyrophoric acid absent) 79
79. Thallus UV + orange 80
79. Thallus not UV + orange 81
80. Thallus granular (soredia-like); apothecia not confluent, disc grey-pruinose; atranorin, zeorin, unknown substance (Rf class 5) **Lecanora** sp.
80. Thallus not granular; apothecia often confluent, disc not pruinose; atranorin and two xanthonenes **Lecidella** sp.
81. Apothecia lecanorioid 82
81. Apothecia lecidiioid 83
82. Usnic acid present **Lecanora pulverulenta**
82. Usnic acid absent **Lecanora leprosa**
83. Thallus C + yellow-orange **Lecidea** sp. 2
83. Thallus C – 84
84. Thallus PD + orange (stictic acid); spores halonate **Porpidia albocaerulescens**
84. Thallus Pd – or PD + pale yellow; spores not halonate 85
85. Thallus K + yellow (atranorin) **Lecidea** sp. 3
85. Thallus K – (no secondary substances) **Lecidea** sp. 1
86. Photobiont trentepohlioid 87
86. Photobiont *Chlorococcaceae* 90
87. Pycnidia frequent, elevated 88
87. Pycnidia not seen 89
88. Pycnidia with an orange pigment in apical parts; conidia often weakly curved, 6–9 \times 1.5–2.2 μm **Opegrapha** sp. 4
88. Pycnidia lacking an orange pigment; conidia straight, 3–5 \times 1 μm **Arthonia** sp. 1
89. Thallus gelatinous, \leq 0.05 mm thick; soralia absent; secondary substances absent **Porina** sp. 3
89. Thallus verruculose, up to 0.2 mm thick; maculate to confluent soralia present; two fatty acids present (Rf class 5 and 5–6) **Dendrographa** sp.
90. Thallus minutely squamulose (0.1–1 \times 0.1–0.3 mm), green with a brown tint **Agonimia pacifica**
90. Thallus not as above 91
91. Thallus UV + orange 92
91. Thallus not UV + orange 93
92. Thallus greenish grey, with patches of soredia-like granules; pycnidia frequent; atranorin, zeorin, unknown substance (Rf class 5) **Lecanora** sp.
92. Thallus yellowish green, entirely granular to mealy; pycnidia unknown; rhizocarpic acid **Chrysothrix** sp.
93. Thallus leprarioid, completely sorediate 94
93. Thallus if sorediate at least partly corticated or with soralia originating from endosubstratal thallus parts 100
94. Thallus C + red; lecanoric acid present **Lepraria cupressicola**
94. Thallus C –; lecanoric acid absent 95
95. Thallus cottony, pale lime green; the triterpenoid lesdainin major substance present **Botryolepraria lesdainii**
95. Thallus leprose, not pale lime green; the

	triterpenoid lesdainin absent	96
96.	Pannaric acid 6-methyl ester major substance present	Lepraria vouauxii
96.	Pannaric acid 6-methyl ester substance absent	97
97.	Stictic acid present	98
97.	Stictic acid absent	99
98.	Medulla thick and whitish	
 ' Lepraria lobificans '	
98.	Medulla not differentiated	Lepraria sp. 1
99.	Usnic acid absent; usually corticolous or lignicolous	Lepraria sp. 3
99.	Usnic acid present; saxicolous or on soil	Lepraria sp. 2
100.	Thallus C + red (gyrophoric acid)	101
100.	Thallus C – (gyrophoric acid absent)	102
101.	Thallus of isidiate to minutely coralloid granules, greenish brown; on bark and wood	Placynthiella icmalea
101.	Thallus sorediate, with a bluish tint; saxicolous	Trapelia placodioides
102.	Pycnidia frequent, elevated	103
102.	Pycnidia not seen	106
103.	Conidia pyriform	104
103.	Conidia not pyriform	105
104.	Thallus with a bluish tint; conidia 3–4 × 2 μm	Fellhanera sp. 1
104.	Thallus green; conidia 4–6 × 1–1.5 μm	Fellhanera sp. 2
105.	Pycnidia elevated, pale, not hollow and chimney-like	Bacidina sp. 1
105.	Pycnidia elevated, white, hollow and chimney-like	Bacidina sp. 3
106.	Thallus not sorediate	107
106.	Thallus sorediate	108
107.	With a bluish tint; zeorin and usnic acid present	Lecanora pulverulenta
107.	Thallus vivid green; no lichen substance detected	Lichen sp. 2
108.	Thallus inapparent, endosubstratal, except for the minute soralia originating from lower bark layers; no secondary substances detected	Lichen sp. 1
108.	Thallus with ± discrete soralia surrounded	

by well-developed thallus; atranorin, one or maybe two fatty acids and unknown substance (Rf class 5) present

..... Lichen sp. 3

Species List

The list is arranged alphabetically. Numbers and/or letters following collector abbreviations indicate the collection number of AF (A. Frisch), GT (G. Thor) or YO (Y. Ohmura). The asterisk in the species list indicates that the species was not found during the inventory 1995–1996 (Kashiwadani and Thor 2000). It should be noted that “*Liquidambar formosana*” in Kashiwadani and Thor (2000) and Ohmura *et al.* (2012) is *Acer buergerianum* (detailed corrections are indicated in the species list below).

1. **Acarospora** sp. Common on dry exposed to slightly shaded rocks and stone walls, found both in 1995–1996 and in 2009–2013. Specimen examined. Sankaku: YO9598, on stone wall (coll. date: 8 March 2013).
2. **Agonimia pacifica** (H. Harada) Diederich Common on shaded stone walls and trees, growing directly on rock or bark, or over soil and bryophytes. Perithecia not seen. Found both in 1995–1996 and in 2009–2013. Specimens examined. Kamidokan: GT29628, on a piece of roof tile in stone wall (coll. date: 8 March 2013). Kanbaku: YO6811, on bark of *Acer pycnanthum* (coll. date: 26 October 2009). Shimodokan: GT29543, on *Quercus* sp. (coll. date: 6 March 2013).
3. **Amandinea punctata** (Hoffm.) Coppins & Scheid. Included as “*Amandinea* sp.” in Kashiwadani and Thor (2000). Common on bark and wood. Specimens examined. Fukiage: AF12/Jp31, on cut face of wooden post (coll. date: 1 December 2011). Honmaru: YO7695, on bark of *Prunus lannesiana* (coll. date: 14 October 2010). YO6843, on *Pinus densiflora* (coll. date: 3 December 2009); YO6855, on base of *Pinus thunbergii* (coll.

- date: 4 December 2009); YO8439, on bark of *Cercidiphyllum japonicum* (coll. date: 1 December 2011). Fukiage: GT29559, on *Pinus thunbergii* (coll. date: 7 March 2013), GT29561, on twigs on the ground (coll. date: 7 March 2013). Sankaku: GT29837, on coniferous tree (coll. date: 18 July 2013).
4. ***Arthonia pertabescens** Nyl. Photobiont trentepohlioid. Ascospores narrow cuneiform, $19\text{--}24 \times 6\text{--}8\ \mu\text{m}$, hyaline to pale brown, 6–7-septate, not constricted at the septa, with thin perispore. Two specimens were collected in 2013. One specimen (AF13/Jp23 pr.p.) is without spores and only tentatively included here. New to the Imperial Palace Grounds.
Specimens examined. Inui: AF13/Jp23 pr.p., on bark of *Acer* sp. (coll. date: 6 March 2013). Ohmichi: AF13/Jp5, on deciduous tree (coll. date: 6 March 2013). Ohmichi: AF13/Jp5, on deciduous tree (coll. date: 6 March 2013).
 5. **Arthonia** sp. 1 Included as “Lichen sp. #3” in Kashiwadani and Thor (2000) [*Liquidambar formosana*” given as substrate for this species in this reference should be *Acer buergerianum*].
The species was collected on deciduous and coniferous trees, and often grows intermixed with other species with trentepohlioid photobiont as *Coenogonium kawanae*, *Enterographa anguinella*, *Opegrapha* sp. 3, and *Ramonia luteola*.
Specimens examined. Chikurin: AF13/Jp1, on bark of *Acer buergerianum* (coll. date: 7 March 2013); GT29591 (coll. date: 7 March 2013). Fukiage: AF13/Jp31, on bark of *Torreya nucifera* (coll. date: 7 March 2013); GT29568, on *Torreya nucifera* (coll. date: 7 March 2013). Kamidokan: AF13/Jp10, on bark of *Pinus thunbergii* (coll. date: 7 March 2013). Sakurada: GT29608, on *Acer buergerianum* (coll. date: 7 March 2013).
 6. ***Arthonia** sp. 2 Lichenicolous on *Physciella melanchra* on one *Acer buergerianum* tree. New to the Imperial Palace Grounds.
Specimen examined. Inui: GT29846, on *Acer buergerianum* (coll. date: 18 July 2013).
 7. ***Aspicilia cinerea** (L.) Körb. Rare on exposed old stone walls. It needs to be investigated if this taxon represents *Aspicilia cinerea* s.str. New to the Imperial Palace Grounds.
Specimen examined. Hanzo: YO7659, on stone wall (coll. date: 13 October 2010).
 8. **Bacidia** sp. 1 Found once on an old, exposed stump in Ohmichi Garden in 1995–1996. Not noted in 2009–2013.
 9. **Bacidia** sp. 2 Found on rocks in semi-shaded and humid habitats at three localities in 1995–1996. Not noted in 2009–2013.
 10. ***Bacidia** sp. 3 This species belongs to the “*Bacidia rubella* group”, characterized by the large, pale to reddish apothecia and acicular spores. The species is rare and was only collected once on *Cinnamomum camphora* in a semi-open deciduous forest. New to the Imperial Palace Grounds.
Specimen examined. Sakurada: GT29614, on bark of *Cinnamomum camphora* (coll. date: 7 March 2013).
 11. **Bacidina** sp. 1 Included as “Lichen sp. #2” in Kashiwadani and Thor (2000). The finding of apothecia in 2013 enabled us to identify the genus of this species. It is distinguished from other *Bacidina* spp. in the Imperial Palace Grounds by the pale elevated pycnidia. The species was found on pebbles close to a building and on a stone forming a bridge over a small stream.
Specimens examined. Kanbaku: GT29574, on stone forming bridge over stream (coll. date: 7 March 2013). Nantei: GT29625, on pebbles (coll. date: 8 March 2013); YO9824, on pebbles (coll. date: 18 July 2013).
 12. ***Bacidina** sp. 2 This species is similar to *Bacidina chlorotricula* (Nyl.) A. L. Sm. but has larger (up to 0.5 mm in diam.), flat

to convex apothecia, and the conidia are formed as fishhooks, $40\text{--}50 \times 1 \mu\text{m}$. The species was found at bases of deciduous trees in a semi-open deciduous forest. New to the Imperial Palace Grounds.

Specimens examined. Fukiage: GT29662, on *Lithocarpus edulis* (coll. date: 8 March 2013); GT29667, on *Machilus thunbergii* (coll. date: 8 March 2013).

13. ***Bacidina** sp. 3 Thallus greenish with white hollow pycnidia. On stones and once also on a deciduous tree root. New to the Imperial Palace Grounds.

Specimens examined. Kanbaku: GT29580, on stone (coll. date: 7 March 2013). Sakurada: GT29619, on stone (coll. date: 7 March 2013).

14. **Botryolepraria lesdainii** (Hue) Canals *et al.* On rocks and soil in habitats characterized by high humidity, deep shade and being sheltered from rain. It is usually not accompanied by any other lichen species but *Lepraria* spp. is often found nearby. It was found at two localities in 1995–1996 and two in 2009–2013.

Specimens examined. Hanzo: YO7649, YO7654, on stone wall (coll. date: 13 October 2010). Shimodokan: GT29550 on old stone wall (coll. date: 6 March 2013).

15. **Buellia** sp. 1 Included as "*Buellia* sp." in Kashiwadani and Thor (2000). The species is distinguished by the immersed apothecia and the minutely warted, 1-septate brown spores. *Buellia* sp. 1 was found on the upper side of a large stone forming a bridge over a small stream. The species was seen in 2009–2013 at the same place but was not collected.

16. ***Buellia** sp. 2 Thallus sorediate with black apothecia. Only found in one locality at the base of *Torreya nucifera*. New to the Imperial Palace Grounds.

Specimen examined. Fukiage: GT29571, on base of *Torreya nucifera* (coll. date: 7 March 2013).

17. **Caloplaca** aff. **citrina** (Hoffm.) Th. Fr.

Included as *Caloplaca citrina* in Kashiwadani and Thor (2000). The *Caloplaca citrina* group is still not revised for Japan, but the species is certainly not identical with *C. citrina* s.str. Within the Imperial Palace Grounds, it is easily recognized by the orange, entirely sorediate, K+ violet-red thallus. This species was found on the same slightly shaded mortar wall (Inui-mon avenue) as in 1995–1996 and now covers several square meters in 2009–2013 (but not collected).

18. **Caloplaca** sp. 1 Included as "*Caloplaca* sp." in Kashiwadani and Thor (2000). A variable species. Common on exposed to slightly shaded rocks and mortar, both in 1995–1996 and in 2009–2013.

Specimens examined. Agency: GT29585, on concrete-wall (coll. date: 7 March 2013). Inui: AF13/Jp14, on pavement (coll. date: 6 March 2013); GT 29523, GT29524, on mortar (coll. date: 6 March 2013). Sakurada: GT29616, on mortar (coll. date: 7 March 2013).

19. ***Caloplaca** sp. 2 Thallus greyish with yellow-orange apothecia. Found once on a species rich rock in a stream. New to the Imperial Palace Grounds.

Specimens examined. Nantei: GT29836, on stone (coll. date: 18 July 2013); YO9595, on rock along a small stream (coll. date: 8 March 2013).

20. ***Candelaria concolor** (Dicks.) Arnold This species was not found in 1995–1996, but rich populations were observed in 2009–2013 (Ohmura *et al.* 2012) [*Liquidambar formosana*] given as substrate for this species in this reference should be *Acer buergerianum*].

Additional specimens examined to Ohmura *et al.* (2012). Honmaru: YO7697, on bark of *Prunus lannesiana* (coll. date: 14 October 2010). Inui: GT29529a, on *Acer buergerianum* (coll. date: 6 March 2013); GT29845a, on *Acer buergerianum* (coll. date: 18 July 2013). Sakurada: GT29618,

- on mortar at roadside (coll. date: 7 March 2013).
21. ***Candelariella** sp. Thallus sorediate. Apothecia not seen. Noted on one *Prunus* × *yedoensis*. New to the Imperial Palace Grounds.
Specimen examined. Inui: GT29530, on *Prunus* × *yedoensis* (coll. date: 6 March 2013).
 22. ***Chaenotheca hygrophila** Tibell Noted in one locality on *Cryptomeria japonica*. New to the Imperial Palace Grounds.
Specimens examined. Kamidokan: AF13/Jp8, GT29645, YO9596, on *Cryptomeria japonica* (coll. date: 8 March 2013).
 23. **Chaenothecopsis nigra** Tibell Found on one tree in a deciduous forest in 1995–1996. Not noted in 2009–2013, but the species is small and easily overlooked.
 24. **Chrysothrix** sp. Included as “*Chrysothrix flavovirens*” in Kashiwadani and Thor (1997, 2000), where it was noted that the Japanese collections only have rhizocarpic acid, while the European populations contain an additional unknown substance. Collected in one locality from the base of an old *Ilex integra* in open deciduous forest in 1995–1996, and from *Chamaecyparis obtusa* and *Pinus thunbergii* in semi-open coniferous forest in 2013.
Specimens examined. Kamidokan: AF13/Jp11, AF13/Jp15, GT29639, YO9597, on bark of *Pinus thunbergii* (coll. date: 8 March 2013); GT29634, on bark of *Chamaecyparis obtusa* (coll. date: 8 March 2013).
 25. **Cladonia caespiticia** (Pers.) Flörke This species was commonly found on soil, stone and *Pinus densiflora* in both 1995–1996 and 2009–2013 (Kashiwadani and Thor 2000, Ohmura *et al.* 2012). Chemistry: fumarprotocetraric acid.
Additional specimen examined to Ohmura *et al.* (2012). Inui: GT29848c, on rock (coll. date: 18 July 2013).
 26. **Cladonia kurokawae** Ahti & S. Stenroos Included as “*Cladonia humilis*” in Kashiwadani and Thor (2000). Chemistry: atranorin and fumarprotocetraric acid. This species was commonly observed on soil, moss and bases of *Pinus densiflora* in both 1995–1996 and 2009–2013 (Kashiwadani and Thor 2000, Ohmura *et al.* 2012).
 27. ***Cladonia ramulosa** (With.) J.R. Laundon This species was not found in 1995–1996. Chemistry: fumarprotocetraric, homosekikaic, sekikaic, and 4'-O-methyl-norhomosekikaic acids. Only poorly developed thalli were collected in 2009 and 2010 (Ohmura *et al.* 2012).
 28. **Coenogonium dilucidum** (Kremp.) Kalb & Lücking Included as “*Dimerella dilucidum*” in Kashiwadani and Thor (2000). Found at the base of an old *Ilex integra* in open deciduous forest in 1995–1996. Not noted in 2009–2013, but the species is small and easily overlooked.
 29. **Coenogonium kawanae** (H. Harada & Vězda) H. Harada Found at Chikurin on one *Acer buergerianum* in 1995–1996 [as “*Liquidambar formosana*” in Kashiwadani and Thor (2000)]. Re-collected on the same tree and another nearby *Acer buergerianum* in 2013.
Specimens examined. Chikurin: GT29599, on *Acer buergerianum* (coll. date: 7 March 2013). Sakurada: GT29612, on *Acer buergerianum* (coll. date: 7 March 2013).
 30. ***Coenogonium pineti** (Ach.) Lücking & Lumbsch Widespread and common on *Pinus thunbergii* and deciduous trees. New to the Imperial Palace Grounds.
Specimens examined. Fukiage: GT29661, on *Lithocarpus edulis* (coll. date: 8 March 2013); GT29558, on *Pinus thunbergii* (coll. date: 7 March 2013). Kamidokan: GT29643, on *Cryptomeria japonica* (coll. date: 8 March 2013); GT29631 (coll. date: 8 March 2013).
 31. ***Cresponea japonica** A. Sakata & H. Harada On *Acer buergerianum*, often together with other species with trente-

- pohlioid photobiont. Recently described by Sakata *et al.* (2009) and similar to the holarctic *C. premnea* (Ach.) Egea & Torrente. New to the Imperial Palace Grounds. Specimens examined. Chikurin: YO9588, on bark of *Acer buergerianum* (coll. date: 7 March 2013); GT29594, on *Acer buergerianum* (coll. date: 7 March 2013). Sankaku: YO9591, on bark of *Acer buergerianum* (coll. date: 7 March 2013). Sakurada: GT29611, on *Acer buergerianum* (coll. date: 7 March 2013).
32. **Dendrographa** sp. Included as “*Opegrapha* sp. #2” in Kashiwadani and Thor (2000). This rare species was found in crevices and vertical rock faces of old, slightly shaded stone walls. Specimen examined. Sankaku: AF13/Jp9, on sheltered steep rock walls (coll. date: 18 July 2013).
33. ***Dirinaria applanata** (Fée) D. D. Awasthi This species was not found in 1995–1996, but rich populations were observed on *Prunus* × *yedoensis* in 2009–2013 (Ohmura *et al.* 2012).
34. **Endocarpon japonicum** H. Harada Common on bark (shaded base of *Prunus* × *yedoensis*), wood, mortar and stone, both in 1995–1996 and 2009–2013. Specimens examined. Hanzo: YO7663, YO7673, on stone wall (coll. date: 13 October 2010); GT29590, on stone wall (coll. date: 7 March 2013). Sakurada: GT29615, on mortar (coll. date: 7 March 2013).
35. **Endocarpon neopallidum** H. Harada Common on trees, rocks and shaded mortar, both in 1995–1996 and 2009–2013. Specimens examined. Inui: YO9561, on base of *Acer palmatum* (coll. date: 6 March 2013); GT29531, on *Prunus* × *yedoensis* (coll. date: 6 March 2013). Ohmichi: YO6856, on humus (coll.: 4 December 2009). Inui: GT29525, on mortar (coll. date: 6 March 2013).
36. ***Endocarpon petrolepideum** (Nyl.) Nyl. ex Hue Found at one locality on stone wall. New to the Imperial Palace Grounds. Specimen examined. Hanzo: YO7662, on stone wall (coll. date: 13 October 2010).
37. **Endocarpon superpositum** H. Harada Widespread on mortar and rocks on shaded stone walls in both 1995–1996 and 2009–2013. Specimens examined. Agency: GT29584, on concrete wall (coll. date: 7 March 2013). Hanzo: YO7645, YO7647, YO7648, YO7650, on concrete (coll. date: 13 October 2013).
38. **Enterographa anguinella** (Nyl.) Redinger Found on one old *Acer buergerianum* in 1995–1996 [as “*Liquidambar formosana*” in Kashiwadani and Thor (2000)]. Found on the same tree and also on *Cercidiphyllum japonicum* at another locality in 2009–2013. Specimens examined. Fukiage: YO8431, on bark of *Cercidiphyllum japonicum* (coll. date: 1 December 2011); AF13/Jp4, AF13/Jp6 pr.p., on bark of *Cercidiphyllum japonicum* (coll. date: 7 March 2013).
39. ***Enterographa hutchinsiae** (Leight.) A. Massal. Rare, found at two localities both on tree bark and rock. New to Japan. This species is usually identified as *E. crassa* (DC) Fée in Japan but differs in the more elongated ascomata, shorter spores and slightly wider conidia (not seen in the collection from the Imperial Palace Grounds). The occurrence of *E. crassa* in Japan needs to be confirmed. Specimens examined. Shimodokan: AF13/Jp19, on sheltered stone wall (coll. date: 6 March 2013). Sakurada: GT29605, on *Acer buergerianum* (coll. date: 7 March 2013).
40. **Fellhanera** sp. 1 Included as “*Fellhanera* sp.” in Kashiwadani and Thor (2000). This species was found at one locality in 1995–1996 and at the same locality in 2013. Specimens examined. Kamidokan: GT29635, on *Chamaecyparis obtusa* (coll. date: 8 March 2013); GT29648, on *Cryp-*

- tomeria japonica* (coll. date: 8 March 2013).
41. ***Fellhanera** sp. 2 Thallus smooth, green. Apothecia not seen. Pycnidia common, elevated, up to 0.05 mm in diam., with black walls exposing a whitish conidia mass at the top; conidia pyriform, $4-6 \times 1-1.5 \mu\text{m}$. Chemistry: no lichen substances detected by TLC. The pyriform conidia indicate the genus *Fellhanera*. However, *Byssoloma* is also a possibility. Found at one locality on *Cryptomeria japonica*. New to the Imperial Palace Grounds.
Specimen examined. Kamidokan: GT29647, on *Cryptomeria japonica* (coll. date: 8 March 2013).
42. ***Flavoparmelia caperata** (L.) Hale This species was not found in 1995–1996, but three thalli 1.1 to 6.4 cm in diam. were noted in 2010 (Ohmura *et al.* 2012).
43. ***Graphis handelii** Zahlbr. Common on bark. New to the Imperial Palace Grounds.
Specimens examined. Inui: YO6825, on bark of *Prunus* \times *yedoensis* (coll. date: 3 December 2009); YO9563, on bark of *Prunus* \times *yedoensis* (coll. date: 6 March 2013). Kanbaku: YO6814, on bark of *Cercidiphyllum japonicum* (coll. date: 26 October 2009). Sakashita: YO9575, on *Machilus thunbergii* (coll. date: 7 March 2013).
44. ***Graphis scripta** (L.) Ach. Found at one locality on bark of *Cercidiphyllum japonicum*. New to the Imperial Palace Grounds.
Specimen examined. Fukiage: YO8432, on bark of *Cercidiphyllum japonicum* (coll. date: 1 December 2011).
45. ***Hyperphyscia crocata** Kashiw. This species was not found in 1995–1996, but rich populations were found on *Acer buergerianum* in 2009–2013 (Ohmura *et al.* 2012; as “on *Liquidambar formosana*”).
46. **Lecania erysibe** (Ach.) Mudd Found at two localities (on mortar in walls) in 1995–1996 and at one locality in 2009–2013.
Specimen examined. Kamidokan: YO7680, on stone wall (coll. date: 13 October 2010).
47. **Lecanora japonica** Müll. Arg. Found at one locality on stone in a paved ditch in 1995–1996. Not noted in 2009–2013.
48. ***Lecanora leprosa** Fée Found at one locality on *Acer* sp. New to the Imperial Palace Grounds.
Specimen examined. Inui: AF13/Jp24, on *Acer* sp. (coll. date: 6 March 2013).
49. **Lecanora pulverulenta** Müll. Arg. Common both in 1995–1996 and 2009–2013, mainly on coniferous trees but occasionally also on deciduous trees.
Specimens examined. Fukiage: YO6804, on bark of *Prunus jamasakura* (coll. date: 26 October 2009); YO8427, on bark of *Prunus mume* (coll. date: 1 December 2011); GT29560, on *Pinus thunbergii* (coll. date: 7 March 2013). Honmaru: YO7700, on bark of *Zelkova serrata* (coll. date: 14 October 2010). Inui: YO6844, on bark of *Pinus densiflora* (coll. date: 3 December 2009).
50. **Lecanora** sp. Included as “*Lecanora* sp. #1” in Kashiwadani and Thor (2000). Common on exposed to slightly shaded stone walls, both in 1995–1996 and 2009–2013.
Specimen examined. Hanzo: GT29589, on stone wall (coll. date: 7 March 2013).
51. **Lecidea** sp. 1 Included as “*Lecidea* sp.” in Kashiwadani and Thor (2000). Found on a slightly shaded, siliceous rock near a pond in 1995–1996. Noted on a stone in a paved ditch (Shimodokan) in 2013, but not collected.
52. ***Lecidea** sp. 2 Thallus pale greenish grey, thin to evanescent, matt, up to 0.02 mm thick, K + yellow, C + yellow-orange, Pd –. Apothecia 0.1–0.15 mm in diam., sparse; disc brown, weakly glossy; margin elevated, concolorous with the disc. Spores rare, $6-7 \times 3-4 \mu\text{m}$. Pycnidia not seen. New to the Imperial Palace Grounds.
Specimens examined. Inui: AF13/Jp20, on bark of *Prunus* \times *yedoensis* (coll. date:

- 6 March 2013). Fukiage: AF13/Jp34, on indet. tree (coll. date: 7 March 2013).
53. ***Lecidea** sp. 3 Thallus white, rimose to irregularly areolate, up to 0.5 mm thick, smooth, K + yellow, C –, Pd –, I –, UV –. Apothecia black, slightly immersed to superficial, up to 0.1 mm in diam.; epithecium green. Asci 8-spored. Spores ellipsoid, simple, hyaline, $11.0 \times 5.0\text{--}5.8 \mu\text{m}$. Chemistry: atranorin, planaic acid, and unidentified substance (Rf class 3, pale). New to the Imperial Palace Grounds.
Specimen examined. Hanzo: YO9825, on stone wall (coll. date: 18 July 2013).
54. **Lecidella** sp. 1 This species was found at two slightly shaded stone walls in 1995–1996 and was common in the same habitat in 2009–2013.
Specimens examined. Kamidokan: YO7677, YO7684, on stone wall (coll. date: 13 October 2010).
55. **Lepraria cupressicola** (Hue) J.R. Laundon Included as “*Lepraria* sp. #4” in Kashiwadani and Thor (2000). Common in both 1995–1996 and 2009–2013, occurring on trees, soil and bricks. Chemistry: zeorin, lecanoric acid and atranorin.
Specimens examined. Fukiage: YO6801, on bark of *Prunus jamasakura* (coll. date: 26 October 2009); YO8187, on bark of *Prunus jamasakura* (coll. date: 21 April 2011). Honmaru: YO7702, on bark of *Prunus jamasakura* f. *pubescens* (coll. date: 14 October 2010). Inui: YO6827, on bark of *Prunus* × *yedoensis* (coll. date: 3 December 2009); YO6849, on bark of *Prunus* × *yedoensis* (coll. date: 4 December 2009); YO6853, on base of *Pinus densiflora* (coll. date: 4 December 2009); GT29526, on *Pinus thunbergii* (coll. date: 6 March 2013); GT29848b, on stone wall (coll. date 18 July 2013). Kamidokan: GT29636, on *Pinus thunbergii* (coll. date: 8 March 2013); GT29644, on *Cryptomeria japonica* (coll. date: 8 March 2013). Kashiko: GT 29657, on *Prunus* sp. (coll. date: 8 March 2013); GT29838b, on *Prunus* sp. (coll. date: 18 July 2013). Sankaku: YO6860, on soil (covered on stone wall) (coll. date: 4 December 2009); GT29620, on brick in shaded stone wall (coll. date: 8 March 2013). Sakashita: GT29557, on *Machilus thunbergii* (coll. date: 7 March 2013).
56. ‘**Lepraria lobificans** Nyl.’ This species was found on trees, soil and stone. Found at two localities in 1995–1996 and at six in 2009–2013. Chemistry: atranorin, zeorin and stictic acid complex. According to Lendemmer (2013), *L. lobificans* auct. should be *L. finckii* (B. de Lesd.) R. C. Harris.
Specimens examined. Chikurin: GT29595, on *Acer buergerianum* (coll. date: 7 March 2013). Fukiage: YO8188, on base of *Prunus jamasakura* (coll. date: 21 April 2011). Hanzo: YO7655, on stone wall (coll. date: 13 October 2010); YO7658, on soil and rock (coll. date: 13 October 2010). Kamidokan: YO7687, on stone wall (coll. date: 13 October 2010). Shimodokan: GT29549, on stone wall (coll. date: 6 March 2013).
57. **Lepraria vouauxii** (Hue) R.C. Harris Included as “*Leproloma vouauxii*” in Kashiwadani and Thor (2000). This species is difficult to distinguish from atypical ‘*L. lobificans*’ and *Lepraria* sp. 3 in the field. However, it is easily identified by the chemistry. Found on rock at two localities both in 1995–1996 and in 2009–2013. Chemistry: pannaric acid 6-methyl ester (major), and traces of accessories.
Specimens examined. Hanzo: YO7669, on rock (coll. date: 13 October 2010). Sankaku: GT29669, on stone wall (coll. date: 8 March 2013).
58. **Lepraria** sp. 1 Included as “*Lepraria* sp. #1” in Kashiwadani and Thor (2000). The species was found on soil at one locality in 1995–1996 and on rock and bark of deciduous trees at two localities in 2009–2013. Chemistry: atranorin, zeorin

- and stictic acid complex.
- Specimens examined. Hanzo: YO7656, on stone wall (coll. date: 13 October 2010). Kanbaku: GT29582, on deciduous tree (coll. date: 7 March 2013).
59. **Lepraria** sp. 2 This species includes both “*Lepraria* sp. #2” and “*Lepraria* sp. #3” in Kashiwadani and Thor (2000). It is distinguished by the usually adpressed, dull greenish grey thalli forming irregular patches up to several cm across, and the chemistry. Common on rocks in 1995–1996 and on deciduous and coniferous trees in 2009–2013. Chemistry: zeorin, usnic acid and unknown substances (minor).
- Specimens examined. Fukiage: GT29566, on deciduous tree (coll. date: 7 March 2013). Inui: GT29522, on *Liquidambar formosana* (coll. date: 6 March 2013); GT29528, on *Acer buergerianum* (coll. date: 6 March 2013); GT29535, on *Liquidambar formosana* (coll. date: 6 March 2013); GT29847, on *Acer buergerianum* (coll. date: 18 July 2013). Kashiko: GT29658, on *Prunus* sp. (coll. date: 8 March 2013).
60. **Lepraria** sp. 3 Included as “*Lepraria* sp. #5” in Kashiwadani and Thor (2000) [“*Liquidambar formosana*” given as substrate for this species in this reference should be *Acer buergerianum*]. This species is distinguished by the patchy, thin and greyish thallus, which also makes it easily overlooked. The chemistry is, however, characteristic. Depauperate specimens of ‘*L. lobificans*’ may be similar, but that species differs by the stictic acid complex. Found on bark of deciduous and coniferous trees at five localities in 1995–1996 and two in 2009–2013. Chemistry: zeorin, unknown substance Rf class 7 and unknown substance Rf class 7–8 (minor or absent).
- Specimens examined. Fukiage: GT29569, on *Torreya nucifera* (coll. date: 7 March 2013). Honmaru: YO7704, on bark of *Cinnamomum camphora* (coll. date: 14 October 2010).
61. **Lichenothelia** sp. 1 This species was found on two dry, exposed stone walls in 1995–1996. Not noted in 2009–2013.
62. **Lichenothelia** sp. 2 This species was found once on a dry, exposed stone wall in 1995–1996. Found at one locality in 2013.
- Specimen examined. Hanzo: GT 29587, on stone wall (coll. date: 7 March 2013).
63. **Lichinella japonica** H. Harada & Hensen A few specimens were collected on a shaded mortar wall in 1995–1996. It was searched for at the same locality in 2013 and a small population was found.
- Specimens examined. Agency: GT 29583, YO9583, on concrete wall (coll. date: 7 March 2013).
64. ***Lithothelium japonicum** H. Harada Occasionally observed at bases of deciduous trees in semi-open habitats. New to the Imperial Palace Grounds.
- Specimens examined. Chikurin: GT29596, on *Acer buergerianum* (coll. date: 7 March 2013). Fukiage: GT29665, on *Acer buergerianum* (coll. date: 8 March 2013). Sakurada: GT29606, GT29610, on *Acer buergerianum* (coll. date: 7 March 2013).
65. ***Micarea** sp. Thallus thin, gelatinous, green, up to 3 cm in diam. Ascomata and pycnidia not seen. Photobiont Chlorococcales, cells up to 6 μm in diam. (micareoid). This species was found on bark of old *Chamaecyparis obtusa* and *Pinus thunbergii* in a steep slope. New to the Imperial Palace Grounds.
- Specimens examined. Kamidokan: GT29633, on *Chamaecyparis obtusa* (coll. date: 8 March 2013); GT29637, on *Pinus thunbergii* (coll. date: 8 March 2013).
66. ***Normandina pulchella** (Borrer) Nyl. Found at the base of one *Prunus* × *yedoensis* in an avenue. New to the Imperial Palace Grounds.
- Specimen examined. Inui: YO9573, on *Prunus* × *yedoensis* (coll. date: 6 March 2013).

67. ***Opegrapha** sp. 1 Thallus brownish (dirty) olive-grey, matt, largely endosubstratal. Ascomata triangular to short lirellate, $0.4\text{--}0.7 \times 0.2\text{--}0.3$ mm, black, epruinose; hymenium I+ pale blue changing to red except for the persistently blue hypothecium, KI+ sky-blue; spores fusiform-acicular, straight to slightly curved, with an $0.5\ \mu\text{m}$ wide epispore, 3–5-septate, $22\text{--}31 \times 4.5\text{--}6\ \mu\text{m}$ (excluding the epispore); epispore forming distinct auricles at both ends at least in young spores. Pycnidia not seen. This species has been collected from *Acer* sp. in one locality. New to the Imperial Palace Grounds.
Specimens examined. Inui: AF13/Jp22, AF13/Jp23 pr.p., on bark of *Acer* sp. (coll. date: 6 March 2013).
68. ***Opegrapha** sp. 2 Thallus pale fawn with patches of pale orange, matt. Ascomata lirellate, up to $1 \times 0.1\text{--}0.2$ mm, black; hymenium I+ pale orange-red, KI+ sky-blue; spores fusiform-acicular, straight, 3–5-septate with the middle cell(s) slightly widened, $25\text{--}30 \times 4\ \mu\text{m}$, with about $1\ \mu\text{m}$ wide epispore (only few mature spores seen). Pycnidia conical, black, $0.1\text{--}0.2$ mm in diam.; conidia curved to occasionally weakly sigmoid, $5\text{--}8(12) \times 1\text{--}1.5\ \mu\text{m}$. This species resembles *O. niveoatra* (Borrer) Laundon, but differs in the larger conical pycnidia. It has been collected from tree bark in one locality. New to the Imperial Palace Grounds.
Specimen examined. Fukiage: AF13/Jp6, on bark of indet. tree (coll. date: 7 March 2013).
69. **Opegrapha** sp. 3 This species was collected from one *Acer buergerianum* [as “*Liquidambar formosana*” in Kashiwadani and Thor (2000)] in 1995–1996. Widespread and frequent on *Acer buergerianum* in 2013.
Specimens examined. Fukiage: AF13/Jp2, on *Acer buergerianum* (coll. date: 7 March 2013); GT29666, on *Acer buergerianum* (coll. date: 7 March 2013). Saku-rada: GT29604, on *Acer buergerianum* (coll. date: 7 March 2013); GT29609, on *Acer buergerianum* (coll. date: 7 March 2013).
70. ***Opegrapha** sp. 4 Thallus whitish, weakly glossy, up to 0.05 mm thick. Ascomata absent. Pycnidia strongly emergent, hemispherical to conical, somewhat irregular, brownish black but covered by thick whitish pruina and with orange pigment in the apical parts, ca. $0.2\text{--}0.4$ mm in diam., $0.2\text{--}0.3$ mm tall; conidia bacilliform, often weakly curved, $6\text{--}9 \times 1.5\text{--}2.2\ \mu\text{m}$. This species was collected from bark of *Acer buergerianum* in one locality. New to the Imperial Palace Grounds.
Specimen examined. Chikurin: GT29592, on *Acer buergerianum* (coll. date: 7 March 2013).
71. ***Parmelinopsis minarum** (Vain.) Elix & Hale This species was not found in 1995–1996, but one small thallus 1.2 cm in diam. was noted in 2010 (Ohmura *et al.* 2012).
72. ***Parmotrema austrosinense** (Zahlbr.) Hale This species was not found in 1995–1996, but two thalli 1.8 and 2.5 cm in diam. were noted in 2010 (Ohmura *et al.* 2012).
73. ***Parmotrema clavuliferum** (Räsänen) Streimann This species was not found in 1995–1996, but two thalli 2.0 and 5.5 cm in diam. were noted in 2009 (Ohmura *et al.* 2012).
74. ***Parmotrema tinctorum** (Despr. ex Nyl.) Hale This species was not found in 1995–1996, but three thalli 1.0 to 1.4 cm in diam. were noted in 2009 and 2010 (Ohmura *et al.* 2012).
75. ***Pertusaria pertusa** (L.) Tuck. Collected in one locality. New to the Imperial Palace Grounds.
Specimen examined. Inui: AF13/Jp26 pr.p., on bark of *Acer* sp. (coll. date: 6 March 2013).
76. ***Pertusaria** sp. Thallus pale olive-grey, slightly shiny, fissured to fissured areolate, slightly warty, to 0.15 mm thick. Fertile warts hemispherical to conical, distinctly

emergent, 1-pored, 0.5–0.7 mm in diam., numerous and crowded in the thallus centre; hymenium to 500 μm tall; spores 8/ascus, 52–60 \times 20–24 μm , with 3–5 μm wide smooth walls. Thallus K–, C–, KC–, Pd+ bluish, UV–. Collected with the former species. New to the Imperial Palace Grounds.

Specimen examined. Inui: AF13/Jp26 pr.p., on bark of *Acer* sp. (coll. date: 6 March 2013).

77. ***Phaeophyscia hispidula** (Ach.) Essl. This species was not found in 1995–1996, but rich populations were observed in 2009–2013 on *Prunus mume* and *Acer buergerianum* [*Liquidambar formosana*” in Ohmura *et al.* (2012) should be *Acer buergerianum*].

Additional specimen examined to Ohmura *et al.* (2012). Shimodokan: GT29544, on *Quercus* sp. (coll. date: 6 March 2013).

78. **Phaeophyscia rubropulchra** (Degel.) Moberg Rich populations were observed in both 1995–1996 and 2009–2013 (Kashiwadani and Thor 2000, Ohmura *et al.* 2012).

Additional specimen examined to Ohmura *et al.* (2012). Fukiage; GT29562, on *Rosa* sp. (coll. date: 7 March 2013).

79. ***Physcia orientalis** Kashiw. This species was not found in 1995–1996, but was common in 2009–2013 (see Ohmura *et al.* 2012).

Additional specimen examined to Ohmura *et al.* (2012). Inui: YO9574, on *Prunus \times yedoensis* (coll. date: 6 March 2013).

80. **Physciella melanchra** (Hue) Essl. Common in both 1995–1996 and 2009–2013 [*Liquidambar formosana*” in Kashiwadani and Thor (2000) and Ohmura *et al.* (2012) should be *Acer buergerianum*].

Additional specimens examined to Ohmura *et al.* (2012). Inui: GT29845c, on *Acer buergerianum* (coll. date: 18 July 2013); GT29533, on *Liquidambar formosana* (coll. date: 6 March 2013).

81. **Placynthiella icmalea** (Ach.) Coppins &

P. James Collected from three localities in 1995–1996 and from one locality in 2009–2013. The species grows on bark of deciduous and coniferous trees as well as on wood.

Specimen examined. Inui: AF12/Jp43, on bark of *Prunus \times yedoensis* (coll. date: 1 December 2011).

82. **Polyblastia** sp. This species was collected from a shaded stone wall in 1995–1996, intermixed with *Endocarpon neopallidum* and *Physciella melanchra*. Not noted in 2009–2013.

83. **Porina hirsuta** Aptroot & K. H. Moon Included as “*Porina* sp. #1” in Kashiwadani and Thor (2000). This species is characterized by the olive-green to olive-brown thallus, hemispherical ascomata ca. 0.2–0.3 mm in diam. with often some curved whitish hairs at the surface, and the 5(–6)-septate fusiform spores. The spores from the examined material of the Imperial Palace are 25–35 \times 5–6 μm and thus slightly longer than reported by Moon and Aptroot (2009) for specimens from Korea (23–27 \times 5–6 μm). *Porina hirsuta* was first reported from Japan including material from the Imperial Palace by Kashiwadani *et al.* (2009). In 1995–1996 the species was collected on a shaded stone wall. In 2009–2013 it was common on trees, rocks and a piece of old roof tile in a crevice of a stone wall.

Specimens examined. Fukiage: YO6815, on bark of *Styrax obassia* (coll. date: 26 October 2009); YO8189, on broad-leaf deciduous tree (coll. date: 21 April 2011); YO9580, on broad-leaf tree (coll. date: 7 March 2013). Fukiage: GT29663, on *Aphananthe aspera* (coll. date: 8 March 2013). Kamidokan: GT29650, on *Hedera helix* (coll. date: 8 March 2013); GT29627, on old roof tile in stone wall (coll. date: 8 March 2013). Kanbaku: GT29579, on deciduous tree (coll. date: 7 March 2013); GT29581, on stone near the stream (coll.

date: 7 March 2013). Sakurada: GT29603, on *Acer buergerianum* (coll. date: 7 March 2013). Shimodokan: GT29547, on root of deciduous tree (coll. date: 6 March 2013).

84. ***Porina leptalea*** (Durieu & Mont.) A.L. Sm. [Fig. 2] Included as "*Porina* sp. #2" in Kashiwadani and Thor (2000). This species was collected from a shaded stone wall in 1995–1996, and from a stone in a small stream in 2013. New to Japan.

Specimen examined. Nantei: GT29831, on stone in stream (coll. date: 18 July 2013).

85. ****Porina*** sp. 1 This species is not the same as "*Porina* sp. #1" (which is now *P. hirsuta*) in Kashiwadani and Thor (2000). Thallus greenish brown, gelatinous, smooth, cracked. Perithecia hemispherical to conical, up to 0.1 mm in diam.; involucrellum blackish (without a purple-violet pigment); asci ca. $45 \times 8 \mu\text{m}$. Spores 3-septate, $22\text{--}23 \times 5 \mu\text{m}$. Photobiont trentepohlioid. Easily overlooked due to the small, black perithecia growing on a shaded, periodically submerged rock at a small waterfall. New to the Imperial Palace Grounds.

Specimen examined. GT29576, on

wet rock at a small water fall (coll. date: 7 March 2013).

86. ****Porina*** sp. 2 Thallus greenish brown, smooth, thin. Perithecia black, hemispherical, without hairs, up to 0.2 mm in diam.; involucrellum blackish (without a purple-violet pigment). Spores 7–8-septate, $40\text{--}41 \times 3 \mu\text{m}$. Photobiont trentepohlioid. This species was found on stone in a small stream intermixed with *Porina leptalea*. New to the Imperial Palace Grounds. This species is not the same as "*Porina* sp. #2" in Kashiwadani and Thor (2000) which is now included as *Porina leptalea*.

Specimen examined. Nantei: GT29622, on stone in stream (coll. date: 8 March 2013).

87. ***Porina*** sp. 3 Included as "*Opegrapha* sp. #1" in Kashiwadani and Thor (2000). The species was found on shaded stone walls.

Specimen examined. Kamidokan: GT29651, on siliceous rock in stone wall (coll. date: 8 March 2013).

88. ***Porpidia albocaerulescens*** (Wulfen) Hertel & Knopf Collected from mortar and rock in three localities in 1995–1996. Common in the same habitat in 2009–2013.

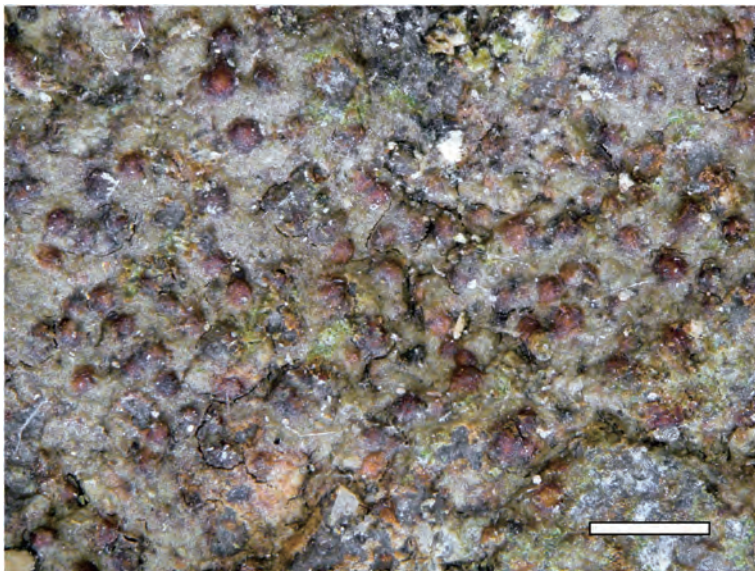


Fig. 2. *Porina leptalea* (GT29831, TNS). Scale: 1 mm.

- Specimen examined. Honmaru: YO7705, on stone wall (coll. date: 14 October 2010).
89. ***Punctelia borreri** (Sm.) Krog This species was not found in 1995–1996, but one thallus 2.9 cm in diam. was found in 2009 (Ohmura *et al.* 2012).
90. **Pyrenopsis** sp. This species was found on an exposed siliceous boulder in a depression which is periodically filled with water in 1995–1996. It was refound on the same boulder in 2013.
- Specimen examined. Nantei: YO9593, on exposed rock (coll. date: 8 March 2013).
91. ***Pyrenula** sp. Thallus crustose, greenish, UV–; ascomata single, ostioles apical; hamathecium mostly unbranched, not interspersed; spores brown, 3-septate, $17.5\text{--}25.1 \times 7.5\text{--}8.4 \mu\text{m}$, lumina angular. New to the Imperial Palace Grounds.
- Specimens examined. Fukiage: YO8433, on bark of *Cercidiphyllum japonicum* (coll. date: 1 December 2011). Kanbaku: YO6813, on bark of *Cercidiphyllum japonicum* (coll. date: 26 October 2009).
92. **Ramonia luteola** Vězda Collected from one old *Acer buergerianum* in 1995–1996 [as “*Liquidambar formosana*” in Kashiwadani and Thor (2000)]. It was searched for on the same tree without success in 2013. A few apothecia were observed at a nearby locality (Sakuradabori, on *Acer buergerianum*).
- Specimen examined. Chikurin: YO9587, on *Acer buergerianum* (coll. date: 7 March 2013).
93. **Scolicosporum umbrinum** (Ach.) Arnold Collected on an exposed stone wall in 1995–1996. Observed on *Prunus* spp. and on exposed rocks in 2013 (Hanzo, not collected).
- Specimens examined. Honmaru: YO7696, on *Prunus lannesiana* (coll. date: 14 October 2010). Inui: YO9562, on *Prunus yedoensis* (coll. date: 6 March 2013).
94. ***Sculptolumina japonica** (Tuck.) Marbach Described from two 19th-century-collections from Shimoda and Yokohama (Tuckerman 1862, 1866; Nylander 1890, as “*Lecidea disculiformis*”) and widespread from Sri Lanka to the Americas (Marbach 2000; Giralt *et al.* 2009). This species was previously known in Japan only from the type collections. It was found on *Quercus* sp. New to the Imperial Palace Grounds.
- Specimens examined. Inui: AF13/Jp13, GT29537, on *Quercus* sp. (coll. date: 6 March 2013).
95. ***Strangospora** sp. Thallus squamulose, the squamules greyish green with a brownish tint, occasionally disrupting apically to expose a hollow with soredia-like structures. Apothecia up to 0.5 mm in diam.; hypothecium colourless; asci >100-spored. Spores globose, $2\text{--}3 \mu\text{m}$ in diam. The species was found on the upper surface of a strongly leaning (almost horizontal) stem of an old *Prunus* sp. The upper surface was covered by bryophytes and the species formed scattered thalli both on the bryophytes and on the bark. New to the Imperial Palace Grounds.
- Specimen examined. Kashiko: GT29656, on *Prunus* sp. (coll. date: 8 March 2013).
96. ***Strigula** sp. Thallus greyish. Spores 1-septate, $16\text{--}19 \times 5 \mu\text{m}$; macroconidia $14\text{--}15 \times 4 \mu\text{m}$. *Strigula aquatica* H. Harada has 7-septate spores. *Strigula nipponica* is found in dry habitats, has slightly shorter spores and thinner macroconidia ($12\text{--}17 \times 2\text{--}3 \mu\text{m}$). Collected in one locality from rock in a stream. New to the Imperial Palace Grounds.
- Specimen examined. Nantei: GT29833, on rock in a stream (coll. date: 18 July 2013).
97. ***Thelidium japonicum** H. Harada Similar to *T. radiatum* H. Harada, but this species is reported to have a more smooth thallus and black perithecia. The material from the Imperial Palace Grounds has a subsquamulose to crustose thallus and perithecia with sometimes a projecting whitish ostiole. Collected in one locality from a stone wall. New to the Imperial

Palace Grounds.

Specimen examined. Hanzo: GT29588, on stone wall (coll. date: 7 March 2013).

98. **Trapelia coarctata** (Sm.) M. Choisy Collected at two localities from slightly shaded rocks near small streams in 1995–1996. Found at one locality in 2013.

Specimen examined. Nantei: GT29835, on rock in a stream (coll. date: 18 July 2013).

99. **Trapelia placodioides** Coppins & P. James Collected at three localities on slightly shaded stone walls in 1995–1996. This species was commonly observed on stone walls in 2009–2013.

Specimens examined. Hanzo: YO7651, YO7657, on stone wall (coll. date: 13 October 2010).

100. **Verrucaria** sp. 1 In 1995–1996 this species was collected on four localities on rocks in wet (sometimes submerged rocks in a small stream), humid or rather exposed habitats (on mortar wall). Collected at one locality in 2013.

Specimens examined. Nantei: GT29832, GT29834, on rock in a stream (coll. date: 18 July 2013).

101. **Verrucaria** sp. 2 This species was collected at one locality on periodically submerged rocks in a small stream in 1995–1996. It was noted on periodically submerged rocks and on a rock forming a bridge over the same stream in 2013.

Specimens examined. Kanbaku: GT 29575, GT29577, on siliceous rock (coll. date: 7 March 2013).

102. ***Verrucaria** sp. 3 Thallus well developed, black, cracked. Perithecia elevated but covered by a thin thallus cover when young, later free, black and often distinctly flat-topped; ostiole often visible as a minute pit, up to 0.2 mm in diam. Spores ellipsoid, 12–15 × 5 μm. On siliceous rock in slightly shaded places. New to the Imperial Palace Grounds.

Specimens examined. Kamidokan: GT29630, on siliceous stone in stone wall (coll. date: 8 March 2013). Nantei: GT29830,

on siliceous stone in stream (coll. date: 18 July 2013).

103. ***Verrucaria** sp. 4 Thallus well developed, grey, cracked. Perithecia 50–90% immersed in the thallus, black, up to 0.2 mm in diam. Spores ellipsoid, 17–19 × 8–9 μm. Similar to *V. nigrescens* Pers. but this species has a dark brown thallus. On exposed mortar together with *Caloplaca* sp. 1. New to the Imperial Palace Grounds.

Specimen examined. Inui: GT29524 (adest. in *Caloplaca* sp. 1), on mortar (coll. date: 6 March 2013).

104. ***Lichen** sp. 1 This species is distinguished by the small soralia with farinose soredia. It can easily be overlooked if only a few scattered soralia are present. Found on bark of deciduous and coniferous trees and on wood. Common both in 1995–1996 and in 2009–2013.

Specimens examined. Chikurin: GT29601, on log in deciduous forest (coll. date: 7 March 2013). Fukiage: GT29570, on *Torreya nucifera* (coll. date: 7 March 2013). Ohmichi: GT29541, on *Sambucus* sp. (coll. date: 6 March 2013). Sakashita: GT29556 (coll. date: 7 March 2013).

105. ***Lichen** sp. 2 This is not the same species as “Lichen sp. #2” in Kashiwadani and Thor (2000) which is now *Bacidina* sp. 1. Thallus of appressed, vivid green squamules. Ascomata not seen but pale round structures up to 0.05 mm in diam. are common, which resemble very young perithecia or pycnidia. Found both on stone, bark at bases of trees and on asphalt. New to the Imperial Palace Grounds.

Specimens examined. Kashiko: GT29654, on old asphalt (coll. date: 8 March 2013). Shimodokan: GT29546, on root of deciduous tree (coll. date: 6 March 2013).

106. **Lichen** sp. 3 Included as “Lichen sp. #4” in Kashiwadani and Thor (2000). The species is distinguished by the thick, cracked thallus, the large soralia and by its chemistry. Collected on a slightly shaded rock

at a pond (in the Fukiage-goyen Palace Garden) in 1995–1996. Not noted in 2009–2013.

Comparison of lichen flora between 1995–1996 and 2009–2013

In 2009–2013, 16 macrolichens and 82 crustose species were found. This is a substantial increase in species diversity compared to the former investigation carried out in 1995–1996 when four macrolichens and 53 crustose lichens were reported (Kashiwadani and Thor 1997, 2000). Of these 57 species, eight species could not be found again during the second inventory. Most of those not rediscovered are minute species that were collected only once or in few localities and may have been overlooked in 2009–2013. Ohmura *et al.* (2012) suggested that the increase in macrolichen diversity in the area was related to the remarkable improvement of air quality due to new regulations regarding exhaust emissions from automobiles in and around Tokyo, established in 2003. The drastic increase in crustose lichen species in the Imperial Palace Grounds as outlined above can also be attributed to increased air quality. Lichens are well-known as sensitive bioindicators for air pollution and known to recolonize urban habitats with improving air quality (Rose and Hawksworth, 1981; Hawksworth and McManus, 1989; Herk *et al.*, 2003; Aptroot and Herk, 2007; Purvis *et al.*, 2008; Isocrono *et al.*, 2007; Munzi *et al.*, 2007; Ohmura *et al.*, 2008).

A species-poor lichen flora has been familiar in urban areas of Japan mainly because of air pollution (Sugiyama *et al.*, 1976; Taoda, 1992; Hamada *et al.*, 1995), but air quality in and around Tokyo has considerably improved following the new regulations. The annual average concentration of sulfur dioxide (SO₂), nitrogen dioxide (NO₂) and suspended particulate matter (SPM) near the Imperial Palace were 0.014 ppm SO₂, 0.052 ppm NO₂ and 0.073 mg/m³ SPM in 1995, compared to 0.003 ppm SO₂, 0.046 ppm NO₂ and 0.034 mg/m³ SPM in 2009 (National Institute for Environmental Studies, 2013).

The specimens of the sixteen species of macrolichens in the Imperial Palace Grounds are generally still of small size. The thalli of the parmelioid species are, for example, mostly less than 3 cm in diam. This small size can be caused by their recent establishment following the improvement in air quality, but also by still suboptimal conditions for lichen growth in central Tokyo. Future monitoring of lichens in the Imperial Palace Grounds should be made in order to investigate the causes of the small thallus size in macrolichens and to further monitor the recovery of the lichen flora.

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皇居における地衣類多様性の増大

大村嘉人・ヨーラン トール・アンドレアス フリッシュ・柏谷博之・文 光喜

皇居における地衣類相を2009年から2013年にかけて調査した。分類学的検討を行った結果、合計98種が確認された。1995年から1996年にかけて行った前回の調査では57種が報告されており、今回の調査では約2倍近い種数に増加した。前回調査の報告種のうち8種を確認することができなかったが、微小な種であるため見落とされた可能性がある。今回の調査で確認された種のうち、*Enterographa hutchinsiae*と*Porina leptalea*（ニキビマルゴケ、新称）は日本新産種である。*Arthonia pertabescens*（ヒメホシゴケ、新称）、*Aspicilia cinerea*、*Chaenotheca hygrophila*、*Coenogonium pineti*、*Cresponaea japonica*、*Endocarpon petrolepideum*、*Graphis handellii*、*G. scripta*、*Lecanora leprosa*（ウスチャシブゴケ、新称）、*Lithothelium japonicum*、*Normandina pulchella*、*Pertusaria pertusa*、*Sculptolumina japonica*、*Thelidium japonicum*は皇居から初めての報告である。前回および今回の調査を通して、属レベルまたは所属不明な地衣類についても49種が確認されているが、それらのうち23種も今回新たに見つかった種である。大幅な地衣類多様性の増大はおそらく2003年より東京都および周辺自治体で実施されているディーゼル車排ガス規制による大気汚染の改善が影響している可能性が考えられる。

なお、本調査の関連論文Ohmura *et al.* (2012)の中で、*Cladonia humilis*に対してヒメジョウゴゴケモドキの名称を与えたが、本名称はすでに*C. subconistea*に対して用いられていたために、*C. humilis*をニセヒメジョウゴゴケ（新称）と訂正する。

Appendix 1. Lichens and related fungi in the Imperial Palace Grounds in 1995–1996 and 2009–2013.

Species	1995–1996	2009–2013	Notes
1. <i>Acarospora</i> sp.	+	+	
2. <i>Agonimia pacifica</i>	+	+	
3. <i>Amandinea punctata</i>	+	+	“ <i>Amandinea</i> sp.” in Kashiwadani and Thor (2000)
4. <i>Arthonia pertabescens</i>	–	+	
5. <i>Arthonia</i> sp. 1	+	+	“Lichen sp. #3” in Kashiwadani and Thor (2000)
6. <i>Arthonia</i> sp. 2	–	+	
7. <i>Aspicilia cinerea</i>	–	+	
8. <i>Bacidia</i> sp. 1	+	–	
9. <i>Bacidia</i> sp. 2	+	–	
10. <i>Bacidia</i> sp. 3	–	+	
11. <i>Bacidina</i> sp. 1	+	+	“Lichen sp. #2” in Kashiwadani and Thor (2000)
12. <i>Bacidina</i> sp. 2	–	+	
13. <i>Bacidina</i> sp. 3	–	+	
14. <i>Botryolepraria lesdainii</i>	+	+	
15. <i>Buellia</i> sp. 1	+	+	“ <i>Buellia</i> sp.” in Kashiwadani and Thor (2000). It was also seen in 2009–2013 but not collected.
16. <i>Buellia</i> sp. 2	–	+	
17. <i>Caloplaca</i> aff. <i>citrina</i>	+	+	This species covers several square meters in 2009–2013 but not collected.
18. <i>Caloplaca</i> sp. 1	+	+	“ <i>Caloplaca</i> sp.” in Kashiwadani and Thor (2000)
19. <i>Caloplaca</i> sp. 2	–	+	
20. <i>Candelaria concolor</i>	–	+	
21. <i>Candelariella</i> sp.	–	+	
22. <i>Chaenotheca hygrophila</i>	–	+	
23. <i>Chaenothecopsis nigra</i>	+	–	
24. <i>Chrysothrix</i> sp.	+	+	“ <i>Chrysothrix flavovirens</i> ” in Kashiwadani and Thor (2000)
25. <i>Cladonia caespiticia</i>	+	+	
26. <i>Cladonia kurokawae</i>	+	+	“ <i>Cladonia humilis</i> ” in Kashiwadani and Thor (2000)
27. <i>Cladonia ramulosa</i>	–	+	
28. <i>Coenogonium dilucidum</i>	+	–	“ <i>Dimerella dilucida</i> ” in Kashiwadani and Thor (2000)
29. <i>Coenogonium kawanae</i>	+	+	“ <i>Dimerella kawanae</i> ” in Kashiwadani and Thor (2000)
30. <i>Coenogonium pineti</i>	–	+	
31. <i>Cresponea japonica</i>	–	+	
32. <i>Dendrographa</i> sp.	+	+	“ <i>Opegrapha</i> sp. #2” in Kashiwadani and Thor (2000)
33. <i>Dirinaria applanata</i>	–	+	
34. <i>Endocarpon japonicum</i>	+	+	
35. <i>Endocarpon neopallidulum</i>	+	+	
36. <i>Endocarpon petrolepideum</i>	–	+	
37. <i>Endocarpon superpositum</i>	+	+	

Appendix 1. Continued

	Species	1995–1996	2009–2013	Notes
38.	<i>Enterographa anguinella</i>	+	+	
39.	<i>Enterographa hutchinsiae</i>	–	+	New to Japan
40.	<i>Fellhanera</i> sp. 1	+	+	“ <i>Fellhanera</i> sp.” in Kashiwadani and Thor (2000)
41.	<i>Fellhanera</i> sp. 2	–	+	
42.	<i>Flavoparmelia caperata</i>	–	+	
43.	<i>Graphis handelii</i>	–	+	
44.	<i>Graphis scripta</i>	–	+	
45.	<i>Hyperphyscia crocata</i>	–	+	
46.	<i>Lecania erysibe</i>	+	+	
47.	<i>Lecanora japonica</i>	+	–	
48.	<i>Lecanora leprosa</i>	–	+	
49.	<i>Lecanora pulverulenta</i>	+	+	
50.	<i>Lecanora</i> sp.	+	+	“ <i>Lecanora</i> sp. #1” in Kashiwadani and Thor (2000)
51.	<i>Lecidea</i> sp. 1	+	+	“ <i>Lecidea</i> sp.” in Kashiwadani and Thor (2000). It was also seen in 2009–2013 but not collected.
52.	<i>Lecidea</i> sp. 2	–	+	
53.	<i>Lecidea</i> sp. 3	–	+	
54.	<i>Lecidella</i> sp.	+	+	
55.	<i>Lepraria cupressicola</i>	+	+	“ <i>Lepraria</i> sp. #4” in Kashiwadani and Thor (2000)
56.	‘ <i>Lepraria lobificans</i> ’	+	+	
57.	<i>Lepraria vouauxii</i>	+	+	“ <i>Lepraria</i> sp. #4” in Kashiwadani and Thor (2000)
58.	<i>Lepraria</i> sp. 1	+	+	“ <i>Lepraria</i> sp. #1” in Kashiwadani and Thor (2000)
59.	<i>Lepraria</i> sp. 2	+	+	Both “ <i>Lepraria</i> sp. #2” and “ <i>Lepraria</i> sp. #3” in Kashiwadani and Thor (2000)
60.	<i>Lepraria</i> sp. 3	+	+	“ <i>Lepraria</i> sp. #5” in Kashiwadani and Thor (2000)
61.	<i>Lichenothelia</i> sp. 1	+	–	
62.	<i>Lichenothelia</i> sp. 2	+	+	
63.	<i>Lichinella japonica</i>	+	+	
64.	<i>Lithothelium japonicum</i>	–	+	
65.	<i>Micarea</i> sp.	–	+	
66.	<i>Normandina pulchella</i>	–	+	
67.	<i>Opegrapha</i> sp. 1	–	+	
68.	<i>Opegrapha</i> sp. 2	–	+	
69.	<i>Opegrapha</i> sp. 3	+	+	
70.	<i>Opegrapha</i> sp. 4	–	+	
71.	<i>Parmelinopsis minarum</i>	–	+	
72.	<i>Parmotrema austrosinense</i>	–	+	
73.	<i>Parmotrema clavuliferum</i>	–	+	
74.	<i>Parmotrema tinctorum</i>	–	+	

Appendix 1. Continued

Species	1995–1996	2009–2013	Notes
75. <i>Pertusaria pertusa</i>	–	+	
76. <i>Pertusaria</i> sp.	–	+	
77. <i>Phaeophyscia hispidula</i>	–	+	
78. <i>Phaeophyscia rubropulchra</i>	+	+	
79. <i>Physcia orientalis</i>	–	+	
80. <i>Physciella melanchra</i>	+	+	
81. <i>Placynthiella icmalea</i>	+	+	
82. <i>Polyblastia</i> sp.	+	–	
83. <i>Porina hirsuta</i>	+	+	“ <i>Porina</i> sp. #1” in Kashiwadani and Thor (2000)
84. <i>Porina leptalea</i>	+	+	“ <i>Porina</i> sp. #2” in Kashiwadani and Thor (2000). New to Japan.
85. <i>Porina</i> sp. 1	–	+	It is not the same as “ <i>Porina</i> sp. #1” in Kashiwadani and Thor (2000).
86. <i>Porina</i> sp. 2	–	+	It is not the same as “ <i>Porina</i> sp. #2” in Kashiwadani and Thor (2000)
87. <i>Porina</i> sp. 3	+	+	“ <i>Opegrapha</i> sp. #1” in Kashiwadani and Thor (2000)
88. <i>Porpidia albocaerulescens</i>	+	+	
89. <i>Punctelia borrieri</i>	–	+	
90. <i>Pyrenopsis</i> sp.	+	+	
91. <i>Pyrenula</i> sp.	–	+	
92. <i>Ramonia luteola</i>	+	+	
93. <i>Scoliciosporum umbrinum</i>	+	+	
94. <i>Sculptolumina japonica</i>	–	+	
95. <i>Strangospora</i> sp.	–	+	
96. <i>Strigula</i> sp.	–	+	
97. <i>Thelidium japonicum</i>	–	+	
98. <i>Trapelia coarctata</i>	+	+	
99. <i>Trapelia placodioides</i>	+	+	
100. <i>Verrucaria</i> sp. 1	+	+	
101. <i>Verrucaria</i> sp. 2	+	+	
102. <i>Verrucaria</i> sp. 3	–	+	
103. <i>Verrucaria</i> sp. 4	–	+	
104. Lichen sp. 1	+	+	
105. Lichen sp. 2	–	+	This is not the same as “Lichen sp. #2” in Kashiwadani and Thor (2000).
106. Lichen sp. 3	+	–	“Lichen sp. #4” in Kashiwadani and Thor (2000)